

UNIT 1.0 – INTRODUCTION TO BIOLOGY (Detailed Explanation)

1. Biology as an Important Scientific Discipline

Biology is the scientific study of life and living organisms. Just like:

- **Mathematics** → Studies numbers, logic, and quantitative relationships
- **Physics** → Studies matter, energy, and forces
- **Chemistry** → Studies composition and reactions of substances
- **Biology** → Studies living systems, from molecules to ecosystems

Why Biology is Equally Important?

1. It explains how life functions.
2. It helps in medical advancements.
3. It supports agriculture and food production.
4. It solves environmental and climate issues.
5. It forms the base of biotechnology and genetic engineering.

Without biology:

- No vaccines
- No antibiotics
- No organ transplantation
- No genetic testing

2. Difference Between Science and Engineering

Science	Engineering
Studies natural phenomena	Applies scientific principles
Focuses on understanding	Focuses on designing & creating

Science	Engineering
Example: How eye works	Example: Designing a camera

Example 1: Human Eye vs Camera

Human Eye	Camera
Natural biological organ	Man-made device
Retina acts as sensor	Film/CCD sensor
Iris controls light	Aperture controls light
Brain processes image	Processor processes image

Conclusion:

Biology studies how the eye naturally works (Science).

Engineering designs a camera inspired by the eye (Application).

Example 2: Bird Flying vs Aircraft

Bird Flying	Aircraft
Natural biological system	Man-made machine
Wings generate lift	Wings generate lift
Uses muscles for energy	Uses engines for energy
Self-repairing	Needs maintenance

Conclusion:

Biology studies aerodynamics of birds.

Engineering applies that knowledge to build airplanes.

3. Most Exciting Aspect of Biology

The most exciting aspect is:

👉 **Life can reproduce, evolve, adapt and self-organize.**

Unlike machines, living organisms:

- Grow
- Repair themselves
- Respond to environment
- Evolve over generations

This makes biology dynamic and complex.

4. Why Do We Need to Study Biology?

1. To understand diseases and cure them.
2. To improve crop production.
3. To protect biodiversity.
4. To understand human body and health.
5. To develop biotechnology and genetic engineering.

Example:

- DNA technology
 - Organ transplantation
 - Stem cell therapy
-

5. 18th Century Biological Observations Leading to Major Discoveries

Scientific discoveries begin with **observation**.

(A) Brownian Motion – Robert Brown

- In 1827, Robert Brown observed pollen grains under a microscope.
- He noticed tiny particles moving randomly in water.
- He thought it was life force initially.
- Later scientists proved it was due to molecular collision.

This led to:

- Proof of molecular motion
- Support for atomic theory
- Foundation of statistical mechanics

👉 Observation → Scientific Law

(B) Thermodynamics – Julius Robert Mayer

- Mayer observed sailors' blood in tropical regions.
- Blood was brighter red.
- He concluded less oxygen was required in warm climates.
- This led to the idea of conservation of energy.

Contribution:

- First law of thermodynamics
- Energy transformation concept

👉 Biological observation → Physics law

Importance of Observation in Science

- Careful observation leads to hypothesis.
- Hypothesis leads to experimentation.
- Experiment leads to discovery.

Biology often gives clues for physics and chemistry discoveries.

CLASSIFICATION

Purpose of Classification

Classification is not just naming organisms.
It helps to:

1. Understand evolutionary relationships.
 2. Study similarities and differences.
 3. Organize vast biodiversity.
 4. Predict characteristics.
-

Hierarchy of Life Forms

Biological hierarchy:

Cell → Tissue → Organ → Organ system → Organism → Population → Community → Ecosystem → Biosphere

This shows organization from simple to complex.

Basis of Classification

(A) Based on Cellularity

1. **Unicellular** – Single cell
Example: Escherichia coli
 2. **Multicellular** – Many cells
Example: Humans, plants
-

(B) Based on Ultrastructure

1. **Prokaryotes**
 - No true nucleus
 - No membrane-bound organelles
 - Example: Bacteria
2. **Eukaryotes**
 - True nucleus
 - Membrane-bound organelles
 - Example: Plants, animals, fungi

(C) Based on Energy & Carbon Utilization**1. Autotrophs**

- Make own food
- Use CO₂
- Example: Plants

2. Heterotrophs

- Depend on others
- Example: Animals

3. Lithotrophs

- Use inorganic compounds
 - Example: Some bacteria
-

(D) Based on Ammonia Excretion**1. Aminotelic**

- Excrete ammonia
- Example: Fish

2. Ureotelic

- Excrete urea
- Example: Humans

3. Uricotelic

- Excrete uric acid
 - Example: Birds
-

(E) Based on Habitat

1. Aquatic – Live in water
 2. Terrestrial – Live on land
-

(F) Molecular Taxonomy – Three Major Domains

Modern classification is based on molecular data.

Three Domains of Life:

1. Bacteria
2. Archaea
3. Eukarya

This system was proposed by Carl Woese using rRNA sequencing.

Same Organism, Multiple Classifications

Example:

Human:

- Multicellular
- Eukaryotic
- Heterotrophic
- Ureotelic
- Terrestrial

Classification depends on criteria used.

Model Organisms in Biology

Scientists use simple organisms to study life processes.

1. **Escherichia coli**
 - Used in molecular biology
 - Study of genes
2. **Saccharomyces cerevisiae**
 - Used in genetics
 - Study of cell cycle
3. **Drosophila melanogaster**
 - Used in inheritance studies
4. **Caenorhabditis elegans**

- Study of development
5. **Arabidopsis thaliana**
- Model plant
6. **Mus musculus**
- Model mammal
-

Conclusion

Unit 1 explains:

- Biology is a fundamental science.
 - Observation is the foundation of discovery.
 - Classification organizes biodiversity.
 - Modern biology uses molecular tools.
 - Model organisms help understand complex life systems.
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UNIT 2.0 – GENETICS (Detailed Explanation)

1. Importance of Genetics

“Genetics is to Biology what Newton’s laws are to Physical Sciences.”

Just as **Isaac Newton** explained motion and laid the foundation of physics, **Gregor Mendel** laid the foundation of biology by discovering the basic laws of inheritance.

Genetics explains:

- How traits pass from parents to offspring
 - Why offspring resemble parents
 - Why variations occur
 - How genetic diseases are inherited
-

2. Mendel’s Laws of Inheritance

Mendel performed experiments on pea plants and proposed two main laws:

(A) Law of Segregation

- Each individual has two alleles for a trait.
- These alleles separate during gamete formation.
- Each gamete carries only one allele.

Example:

If genotype = Tt

Gametes = T and t

👉 During fertilization, alleles combine again.

Biological importance:

Explains how traits are inherited generation to generation.

(B) Law of Independent Assortment

- Genes for different traits assort independently.
- Inheritance of one trait does not affect another (if genes are on different chromosomes).

Example:

Seed color and seed shape in pea plants.

👉 This explains genetic variation.

3. Concept of Allele

- A gene is a DNA segment controlling a trait.
- Different forms of a gene are called **alleles**.

Example:

Gene for height:

- T = Tall
- t = Dwarf

Possible genotypes:

- TT (homozygous)
- Tt (heterozygous)

- tt (homozygous)
-

4. Dominance and Recessiveness

Dominant Allele

- Expressed even if one copy present.
- Example: T (Tall)

Recessive Allele

- Expressed only when both alleles are recessive.
- Example: tt (Dwarf)

👉 Dominance does not mean stronger; it only means expressed in heterozygous condition.

5. Mitosis and Meiosis (Genetic Perspective)

Focus: How genetic material passes to offspring.

(A) Mitosis

- Occurs in somatic (body) cells.
- Produces two identical daughter cells.
- Maintains chromosome number.
- Important for growth and repair.

👉 No genetic variation created.

(B) Meiosis

- Occurs in germ cells (gamete formation).
- Produces four haploid cells.
- Reduces chromosome number by half.
- Crossing over occurs.

Importance in Genetics:

1. Maintains chromosome number across generations.

2. Creates genetic variation.
3. Allows recombination.

👉 Meiosis ensures proper transmission of genetic material.

6. Gene Mapping

Gene mapping determines:

- Location of genes on chromosome.
- Distance between genes.

It is based on recombination frequency.

If recombination frequency = 1%

→ Distance = 1 map unit (centiMorgan)

Mapping helps:

- Identify disease genes.
 - Understand chromosome structure.
-

7. Gene Interaction

Sometimes one gene affects another gene's expression.

This is called gene interaction.

Epistasis

- One gene masks or modifies another gene.
- The masking gene is called epistatic gene.

Example:

Coat color in animals.

👉 Epistasis modifies Mendelian ratios.

8. Mapping Phenotype to Genes

Phenotype = Observable trait

Genotype = Genetic makeup

Scientists map:

Trait → Gene → DNA sequence → Chromosome location

Example:

Blood group phenotype → ABO gene → Chromosome 9

This helps in:

- Disease diagnosis
 - Genetic testing
 - Personalized medicine
-

9. Single Gene Disorders in Humans

These are caused by mutation in a single gene.

(A) Autosomal Recessive Disorders

1. **Sickle-cell disease**
 - Mutation in hemoglobin gene
 - Causes abnormal RBC shape
 2. **Cystic fibrosis**
 - Affects lungs and pancreas
-

(B) Autosomal Dominant Disorders

1. **Huntington's disease**
 - Affects nervous system
-

(C) X-linked Disorders

1. **Hemophilia**
 - Blood clotting defect
 2. **Color blindness**
 - Difficulty distinguishing colors
-

10. Concept of Complementation (Human Genetics)

Complementation occurs when:

Two individuals with similar recessive phenotypes produce normal offspring because mutations are in different genes.

Example:

If two deaf parents have different genetic mutations, their child may have normal hearing.

This shows:

- Mutation may be in different genes.
- Genes can complement each other.

Complementation test helps:

- Identify whether mutations are in same gene or different genes.
-

11. Why Genetics is Fundamental to Biology

Genetics explains:

- Evolution
- Disease
- Development
- Variation
- Biotechnology
- Gene therapy

Modern genetics includes:

- DNA sequencing
 - CRISPR
 - Gene editing
 - Personalized medicine
-

Conclusion

Unit 2 emphasizes:

- Mendel's laws are the foundation of inheritance.
- Meiosis ensures genetic continuity.

- Gene interactions modify inheritance.
- Mapping links phenotype to genotype.
- Single gene disorders show medical importance.
- Complementation explains genetic complexity.

Molecules of Life – Detailed Explanation

Purpose of the Topic

The main purpose is to understand that:

👉 **All living organisms are made of the same basic molecular building blocks,** yet life appears extremely diverse — from bacteria to humans, from algae to elephants.

This diversity arises not from different basic materials, but from:

- Different combinations
- Different structures
- Different organization of the same molecules

Just like:

- Same 26 letters → Millions of words
- Same Lego blocks → Different structures

1. Monomers and Polymers

Monomer

- Small, simple molecular unit.
- Can join with other monomers.

Polymer

- Large molecule made of repeating monomer units.
- Formed by chemical bonding (usually covalent bonds).

Example:

Monomer	Polymer
Glucose	Starch

Monomer	Polymer
Amino acids	Proteins
Nucleotides	DNA/RNA

👉 Biological macromolecules are polymers built from monomers.

2. Carbohydrates (Sugars, Starch & Cellulose)

Carbohydrates are made of:

- Carbon (C)
- Hydrogen (H)
- Oxygen (O)

General formula: $(CH_2O)_n$

(A) Sugars (Monosaccharides)

Example: Glucose

- Smallest carbohydrate unit
- Soluble in water
- Immediate energy source

Glucose is the basic building block of many carbohydrates.

(B) Starch

- Polymer of glucose.
- Found in plants.
- Storage form of energy in plants.
- Easily digestible by humans.

Starch structure:

- Glucose units linked by α -glycosidic bonds.

(C) Cellulose

- Also polymer of glucose.
- Major component of plant cell wall.
- Humans cannot digest cellulose.
- Provides structural support to plants.

Difference between starch and cellulose:

- Both made of glucose.
- Bond type differs (α vs β linkage).
- Different 3D structure \rightarrow Different function.

👉 Same monomer (glucose), different polymer structure \rightarrow Different function.

3. Amino Acids and Proteins

(A) Amino Acids (Monomers)

Basic structure:

- Amino group ($-\text{NH}_2$)
- Carboxyl group ($-\text{COOH}$)
- Hydrogen
- R-group (variable side chain)

There are 20 standard amino acids.

(B) Proteins (Polymers)

- Made of amino acids joined by peptide bonds.
- Long chains called polypeptides.
- Fold into specific 3D shapes.

Protein levels of structure:

1. Primary – Amino acid sequence
2. Secondary – Alpha helix / Beta sheet

3. Tertiary – 3D folding
4. Quaternary – Multiple chains

Functions of proteins:

- Enzymes
- Hormones
- Antibodies
- Structural proteins
- Transport proteins

👉 Small change in amino acid sequence can change entire protein function.

4. Nucleotides and DNA/RNA

(A) Nucleotide (Monomer)

Each nucleotide has:

1. Nitrogen base
2. Sugar
3. Phosphate group

Types of bases:

- Adenine (A)
 - Thymine (T)
 - Cytosine (C)
 - Guanine (G)
 - Uracil (U in RNA)
-

(B) DNA (Deoxyribonucleic Acid)

Structure discovered by
James Watson and
Francis Crick

Features:

- Double helix

- Complementary base pairing (A-T, G-C)
- Stores genetic information

Function:

- Heredity
 - Blueprint for proteins
-

(C) RNA (Ribonucleic Acid)

- Single stranded
- Contains uracil instead of thymine
- Involved in protein synthesis

Types:

- mRNA
- tRNA
- rRNA

👉 DNA stores information, RNA helps express it.

5. Two-Carbon Units and Lipids

Lipids are made mainly from:

- Fatty acids
 - Glycerol
-

(A) Two-Carbon Units (Acetyl-CoA Concept)

Fatty acids are synthesized by adding two-carbon units repeatedly.

These two-carbon units:

- Come from acetyl-CoA
 - Build long hydrocarbon chains
-

(B) Lipids

Types:

- Fats (Triglycerides)
- Phospholipids
- Steroids

Functions:

- Energy storage
- Cell membrane formation
- Hormones
- Insulation

Phospholipids

- Major component of cell membrane.
- Form lipid bilayer.
- Have hydrophilic head and hydrophobic tail.

👉 Lipids are not true polymers but large biological molecules.

Comparison of Major Biological Molecules

Molecule	Monomer	Polymer	Function
Carbohydrates	Glucose	Starch	Energy
Proteins	Amino acids	Polypeptides	Enzymes, structure
Nucleic acids	Nucleotides	DNA/RNA	Genetic info
Lipids	Fatty acids	Triglycerides	Energy storage

Key Concept

All life forms:

- Use same amino acids
- Use same nucleotides
- Use glucose for energy
- Use lipid membranes

Yet diversity arises because:

- Different sequences
- Different structures
- Different regulation
- Different gene expression

Conclusion

- ✓ Life is built from a common molecular toolkit.
- ✓ Monomers form polymers.
- ✓ Structure determines function.
- ✓ Small molecular differences create huge biological diversity.

UNIT 3.0 – ENZYMES (Detailed Explanation)

Part 1: ENZYMES

Purpose

Without catalysis, life would not exist on Earth.

Chemical reactions in cells are extremely slow under normal conditions. Enzymes speed up these reactions millions of times.

👉 Example: Digestion, respiration, DNA replication — all require enzymes.

1. What Are Enzymes?

- Biological catalysts
- Mostly proteins
- Highly specific

- Reusable
- Lower activation energy

Some enzymes are RNA molecules (ribozymes).

2. How to Monitor Enzyme-Catalyzed Reactions

We measure either:

1. Substrate concentration decrease
2. Product formation increase
3. Change in color (spectrophotometer)
4. pH change
5. Gas formation

Common methods:

- UV-Visible spectrophotometry
- Radioactive labeling
- Fluorescence assays

👉 Reaction rate = Change in concentration per unit time.

3. How Does an Enzyme Catalyze a Reaction?

Enzymes lower **activation energy** by:

1. Stabilizing transition state
 2. Bringing substrates close together
 3. Proper orientation of substrates
 4. Strain/distortion of bonds
 5. Acid-base catalysis
 6. Covalent catalysis
-

4. Enzyme Classification

According to IUBMB, enzymes are divided into 6 major classes:

1. **Oxidoreductases** – Oxidation-reduction reactions
 2. **Transferases** – Transfer functional groups
 3. **Hydrolases** – Hydrolysis reactions
 4. **Lyases** – Break bonds without ATP
 5. **Isomerases** – Rearrangement reactions
 6. **Ligases** – Join molecules using ATP
-

5. Mechanism of Enzyme Action

Two main models:

(A) Lock and Key Model

Proposed by **Emil Fischer**

- Active site is rigid.
- Substrate fits perfectly.

(B) Induced Fit Model

Proposed by **Daniel Koshland**

- Active site changes shape after substrate binds.
 - More accurate model.
-

6. Examples of Enzyme Mechanism

Example 1: Lysozyme

- Breaks bacterial cell wall.
- Uses acid-base catalysis.
- Stabilizes transition state.

Example 2: DNA Polymerase

- Adds nucleotides during DNA replication.
 - Uses metal ion catalysis.
 - Highly specific and accurate.
-

7. Enzyme Kinetics

Study of reaction rates.

Basic reaction:



Where:

- E = Enzyme
 - S = Substrate
 - ES = Enzyme-substrate complex
 - P = Product
-

Michaelis-Menten Equation

Proposed by:

Leonor Michaelis

Maud Menten

Key Parameters:

(A) V_{max}

- Maximum reaction velocity.
- When enzyme is saturated.

(B) K_m (Michaelis constant)

- Substrate concentration at half V_{max} .
- Indicates enzyme affinity.

Low K_m → High affinity

High K_m → Low affinity

Why Are Kinetic Parameters Important?

1. Understand enzyme efficiency
2. Compare enzymes
3. Drug design
4. Diagnose diseases
5. Understand metabolic regulation

Example:
Cancer drugs target specific enzyme kinetics.

8. RNA Catalysis (Ribozymes)

Not all enzymes are proteins.

Catalytic RNA discovered by:

Thomas Cech

RNA molecules can:

- Self-splice
- Catalyze reactions

Examples:

- rRNA in ribosome
- Self-splicing introns

👉 Suggests early life may have been RNA-based (RNA world hypothesis).

PART 2: INFORMATION TRANSFER

Purpose

The molecular basis of coding and decoding genetic information is universal.

All organisms:

- Use DNA
 - Use same genetic code
 - Use RNA intermediates
 - Use ribosomes for protein synthesis
-

1. DNA as Genetic Material

Proved by experiments:

1. Griffith experiment
2. Avery-MacLeod-McCarty experiment

3. Hershey-Chase experiment

Structure described by:

James Watson

Francis Crick

2. Hierarchy of DNA Structure

(A) Primary Structure

- Linear nucleotide sequence.

(B) Secondary Structure

- Double helix.
- Complementary base pairing (A-T, G-C).

(C) Tertiary Structure

- Supercoiling.

(D) Nucleosomes

- DNA wrapped around histone proteins.
 - Forms chromatin.
 - Organized into chromosomes.
-

3. Concept of Genetic Code

- DNA sequence → RNA → Protein
- Triplet codon system.
- 3 nucleotides = 1 amino acid.

Example:

AUG = Methionine (Start codon)

4. Properties of Genetic Code

(A) Universal

Almost all organisms use same code.

(B) Degenerate

One amino acid can have multiple codons.

Example:
Leucine has 6 codons.

(C) Non-overlapping

Each base is read once.

(D) Commaless

No gaps between codons.

5. Define Gene in Terms of Complementation

Complementation test:

If two mutations produce normal phenotype together → mutations are in different genes.

Gene defined as:

Unit of function identified by complementation.

6. Define Gene in Terms of Recombination

Gene is also:

Unit of recombination.

Recombination frequency:

- Measures genetic distance.
 - Shows gene structure.
-

Central Dogma of Molecular Biology

Proposed by:

Francis Crick

DNA → RNA → Protein

This is universal principle of life.

Conclusion

- ✓ Enzymes make life possible by catalysis.
- ✓ Kinetics explains enzyme efficiency.
- ✓ RNA can also act as enzyme.
- ✓ DNA stores information universally.

- ✓ Genetic code is universal and degenerate.
 - ✓ Gene defined by function and recombination.
-

UNIT 4.0 – Macromolecular Analysis (Detailed Explanation)

Purpose of the Unit

This unit explains:

- 👉 How biological processes can be analyzed at a **reductionistic level**.

What is Reductionism?

Reductionism means:

- Breaking complex biological systems
- Into smaller components
- Studying structure and function at molecular level

Example:

Instead of studying whole organism digestion →
We study digestive enzymes →
Then protein structure →
Then amino acid sequence.

Modern biology studies life at:

- Molecular level
 - Atomic level
 - Structural level
-

1. Proteins – Structure and Function

Proteins are the most functionally diverse macromolecules in living organisms.

They are:

- Polymers of amino acids
- Folded into specific 3D structures

- Highly specific in function
-

Hierarchy of Protein Structure

Protein structure is organized into 4 levels:

1. Primary Structure

- Linear sequence of amino acids.
- Linked by peptide bonds.
- Determined by DNA sequence.

Example:

Ala–Gly–Ser–Val–Leu...

👉 Even one amino acid change can alter protein function.

Example: Sickle cell anemia caused by single amino acid mutation.

2. Secondary Structure

Local folding patterns due to hydrogen bonding.

Two main types:

(A) Alpha Helix

- Spiral structure
- Stabilized by hydrogen bonds

(B) Beta Pleated Sheet

- Sheet-like structure
- Hydrogen bonds between strands

These structures were described by

Linus Pauling

3. Tertiary Structure

- Complete 3D folding of a single polypeptide.
- Stabilized by:

- Hydrogen bonds
- Disulfide bonds
- Ionic interactions
- Hydrophobic interactions

Determines:

- Active site shape
- Protein function

If tertiary structure is disrupted → protein denatures.

4. Quaternary Structure

- Two or more polypeptide chains.
- Form functional protein complex.

Example:

Hemoglobin has 4 subunits.

Proteins as Functional Molecules

1. Proteins as Enzymes

- Catalyze biochemical reactions.
- Highly specific.
- Example: DNA polymerase, amylase.

Without enzymes:

- Metabolism would be too slow for life.
-

2. Proteins as Transporters

- Move molecules across membranes.
- Carry substances in blood.

Examples:

- Hemoglobin → oxygen transport

- Membrane channel proteins → ion transport
-

3. Proteins as Receptors

- Detect signals.
- Trigger cellular responses.

Example:

- Insulin receptor
- Hormone receptors

Signal binding → conformational change → cellular response.

4. Proteins as Structural Elements

Provide mechanical strength.

Examples:

- Collagen (connective tissue)
 - Keratin (hair, nails)
 - Actin and myosin (muscle contraction)
-

Why Study Protein Structure?

Understanding structure helps us:

1. Predict protein function
2. Design drugs
3. Understand diseases
4. Develop biotechnology tools

Example:

Many drug molecules bind to specific protein active sites.

Macromolecular Analysis Techniques

To analyze proteins at reductionistic level:

1. X-ray crystallography

2. NMR spectroscopy
3. Cryo-electron microscopy
4. SDS-PAGE
5. Mass spectrometry

These techniques allow:

- Structure determination
- Molecular weight analysis
- Interaction studies

Structure–Function Relationship

Key principle in biology:

👉 Structure determines function.

Example:

- Enzyme active site shape determines substrate specificity.
- Hemoglobin structure allows oxygen binding.

If structure changes → function changes.

Reductionistic Understanding of Biological Processes

Example: Muscle Contraction

Instead of studying whole muscle:

- Study actin protein
- Study myosin protein
- Study ATP binding
- Study molecular interactions

This molecular-level understanding explains:

- Movement
- Disease
- Drug action

Conclusion

- ✓ Biological processes can be studied at molecular level.
 - ✓ Proteins are central macromolecules of life.
 - ✓ Protein structure has four hierarchical levels.
 - ✓ Proteins function as enzymes, transporters, receptors, and structural elements.
 - ✓ Understanding protein structure explains biological function.
-

UNIT 5.0 – METABOLISM (Detailed Explanation)

Purpose of the Unit

The fundamental principles of energy transactions are the same in:

- Physical world
- Biological world

Living organisms do not violate physical laws.
They obey the laws of **Laws of Thermodynamics**.

Biology is basically applied thermodynamics inside living cells.

1. What is Metabolism?

Metabolism = Sum total of all chemical reactions in a cell.

Two types:

1. Catabolism

- Breakdown reactions
- Release energy
- Example: Glucose breakdown

2. Anabolism

- Synthesis reactions
 - Require energy
 - Example: Protein synthesis
-

2. Thermodynamics in Biological Systems

Thermodynamics studies energy changes.

First Law of Thermodynamics

Energy cannot be created or destroyed.
It can only change form.

In biology:

- Light → Chemical energy (photosynthesis)
 - Chemical energy → ATP → Mechanical work
-

Second Law of Thermodynamics

Entropy (disorder) of universe increases.

Cells maintain order by:

- Taking energy from environment
 - Releasing heat
-

3. Exothermic vs Endothermic

These terms refer to **heat change**.

Exothermic Reaction

- Releases heat.
- ΔH is negative.

Example:

Combustion of glucose.

Endothermic Reaction

- Absorbs heat.
 - ΔH is positive.
-

4. Exergonic vs Endergonic

These terms refer to **free energy change (ΔG)**.

Exergonic Reaction

- Releases free energy.
- $\Delta G < 0$
- Spontaneous.

Endergonic Reaction

- Requires energy.
- $\Delta G > 0$
- Non-spontaneous.

⚠ Important:

Exothermic \neq Exergonic

Endothermic \neq Endergonic

Biological systems depend on **free energy (ΔG)**, not just heat.

5. Concept of Free Energy (G)

Free energy determines spontaneity.

Gibbs Free Energy Equation:

$$\Delta G = \Delta H - T\Delta S$$

Where:

- ΔH = Enthalpy (heat)
 - T = Temperature
 - ΔS = Entropy
-

Spontaneity

- $\Delta G < 0 \rightarrow$ Spontaneous
 - $\Delta G > 0 \rightarrow$ Non-spontaneous
 - $\Delta G = 0 \rightarrow$ Equilibrium
-

6. Equilibrium Constant (Keq)

Keq tells:

- Ratio of products to reactants at equilibrium.

Relationship with free energy:

$$\Delta G^\circ = -RT \ln K_{eq}$$

Where:

- R = Gas constant
- T = Temperature

If:

- $K_{eq} > 1 \rightarrow$ Reaction favors products
- $K_{eq} < 1 \rightarrow$ Reaction favors reactants

This helps predict reaction direction in metabolism.

7. ATP – Energy Currency of Cell

ATP = Adenosine Triphosphate

- Contains high-energy phosphate bonds.
- Hydrolysis releases energy.

ATP \rightarrow ADP + Pi + Energy

ATP couples:

- Exergonic reactions
- To drive endergonic reactions

Example:

Protein synthesis requires ATP.

👉 ATP acts like rechargeable battery.

8. Breakdown of Glucose (Cellular Respiration)

Overall reaction:

Glucose + O₂ \rightarrow CO₂ + H₂O + ATP

(A) Glycolysis

- Occurs in cytoplasm.

- Glucose → 2 Pyruvate
 - Produces:
 - 2 ATP
 - 2 NADH
-

(B) Krebs Cycle (Citric Acid Cycle)

Discovered by

Hans Krebs

- Occurs in mitochondria.
 - Pyruvate → Acetyl-CoA → CO₂
 - Produces:
 - NADH
 - FADH₂
 - ATP
-

(C) Electron Transport Chain

- Uses NADH & FADH₂
- Produces large amount of ATP
- Oxygen is final electron acceptor

Total ATP ≈ 30–32 per glucose molecule.

👉 This is energy-yielding metabolism.

9. Synthesis of Glucose (Photosynthesis)

Overall reaction:



Occurs in chloroplasts.

Two Stages:

(A) Light Reactions

- Produce ATP and NADPH.
- Release O₂.

(B) Calvin Cycle

- Fixes CO₂.
- Produces glucose.

Photosynthesis is:

- Endergonic process.
- Requires light energy.

👉 Opposite of respiration.

10. Energy-Yielding vs Energy-Consuming Reactions

Energy-Yielding (Catabolic)

- Glycolysis
- Krebs cycle
- Beta oxidation

Energy-Consuming (Anabolic)

- DNA synthesis
- Protein synthesis
- Photosynthesis
- Fatty acid synthesis

Cells couple these reactions using ATP.

11. Concept of Energy Charge

Energy charge reflects cellular energy status.

Formula:

$$\text{Energy Charge} = \frac{(\text{ATP} + \frac{1}{2} \text{ADP})}{(\text{ATP} + \text{ADP} + \text{AMP})}$$

Range:

- 0 (all AMP)

- 1 (all ATP)

Healthy cells maintain:
Energy charge $\approx 0.8-0.95$

Low energy charge:
→ Activate catabolism

High energy charge:
→ Activate anabolism

Integration of Metabolism

Metabolism is interconnected.

Example:

- Glucose → Pyruvate
- Pyruvate → Amino acids
- Amino acids → Proteins

All pathways are integrated networks.

Why Study Metabolism?

1. Understand diseases (diabetes, cancer)
 2. Drug development
 3. Biotechnology
 4. Energy balance
 5. Aging and obesity research
-

Conclusion

- ✓ Biological systems obey thermodynamic laws.
- ✓ ΔG determines spontaneity.
- ✓ K_{eq} relates to free energy.
- ✓ ATP is universal energy currency.
- ✓ Respiration releases energy.
- ✓ Photosynthesis stores energy.
- ✓ Energy charge regulates metabolism.

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UNIT 6.0 – MICROBIOLOGY, PLANT PHYSIOLOGY & ECOLOGY (Detailed Explanation)

PART 1: MICROBIOLOGY

1. Concept of Single-Celled Organisms

Single-celled organisms (unicellular organisms):

- Consist of only one cell
- Perform all life functions within one cell
- Reproduce rapidly
- Adapt quickly

Examples:

- Escherichia coli
- Saccharomyces cerevisiae

Despite being single-celled, they:

- Grow
- Respire
- Reproduce
- Respond to environment

👉 A single cell can function as a complete organism.

2. Concept of Species and Strains

Species (Microbiology Concept)

In microbes:

- Species defined based on genetic similarity
- DNA sequence similarity (16S rRNA analysis)

Example:

Escherichia coli is one species.

Strain

- Genetic variant within a species.
- Differences in virulence, metabolism, resistance.

Example:

E. coli K-12 (lab strain)

E. coli O157:H7 (pathogenic strain)

👉 Species = broader group

👉 Strain = specific variant

3. Identification & Classification of Microorganisms

(A) Morphological Methods

- Shape (coccus, bacillus, spirillum)
- Gram staining

(B) Biochemical Tests

- Sugar fermentation
- Enzyme production

(C) Molecular Methods

- DNA sequencing
- PCR
- 16S rRNA analysis

Modern classification based on molecular phylogeny proposed by Carl Woese

Three Domains:

- Bacteria
 - Archaea
 - Eukarya
-

4. Microscopy

Microscopy allows visualization of microorganisms.

Types:

1. Light microscope
2. Phase contrast microscope
3. Fluorescence microscope
4. Electron microscope (SEM & TEM)

Electron microscopy gives:

- High resolution
 - Ultrastructural details
-

5. Ecological Aspects of Single-Celled Organisms

Microorganisms are found everywhere:

- Soil
- Water
- Air
- Human body
- Extreme environments

Roles:

- Decomposition
- Nitrogen fixation
- Carbon cycling
- Symbiosis
- Pathogenesis

Example:

Rhizobium fixes nitrogen in plants.

6. Sterilization and Media Composition

Sterilization

Process of killing all microorganisms.

Methods:

- Autoclaving (steam under pressure)

- Dry heat
 - Filtration
 - Radiation
 - Chemical sterilization
-

Culture Media

Media provide nutrients for growth.

Types:

1. Simple media
2. Enriched media
3. Selective media
4. Differential media

Components:

- Carbon source
 - Nitrogen source
 - Minerals
 - Vitamins
 - Water
-

7. Growth Kinetics of Microorganisms

Bacterial growth curve has 4 phases:

1. Lag phase
2. Log (exponential) phase
3. Stationary phase
4. Death phase

Growth follows exponential equation:

$$N = N_0 \times 2^n$$

Where:

- N = Final cells
- N_0 = Initial cells
- n = Number of generations

Generation time:

Time required for population to double.

PART 2: PLANT PHYSIOLOGY

1. Transpiration

Loss of water vapor from plant leaves.

Occurs through:

- Stomata
- Cuticle
- Lenticels

Functions:

- Maintains water movement
- Cooling effect
- Nutrient transport

Driven by:

Transpiration pull (cohesion-tension theory).

2. Mineral Nutrition

Plants require:

Macronutrients:

- Nitrogen
- Phosphorus
- Potassium
- Calcium
- Magnesium

- Sulfur

Micronutrients:

- Iron
- Zinc
- Copper
- Manganese

Functions:

- Nitrogen → Proteins
- Magnesium → Chlorophyll
- Phosphorus → ATP

Deficiency causes:

- Chlorosis
 - Stunted growth
 - Necrosis
-

PART 3: ECOLOGY

1. Ecosystem

An ecosystem is a functional unit of nature where:

Biotic components interact with Abiotic components.

Components of Ecosystem

(A) Biotic Factors

- Producers
- Consumers
- Decomposers

(B) Abiotic Factors

- Water

- Soil
 - Temperature
 - Light
 - Air
-

Types of Ecosystems

1. Terrestrial (forest, desert, grassland)
 2. Aquatic (pond, river, ocean)
-

Flow of Matter and Energy

Energy flow:

Sun → Producers → Consumers → Decomposers

Energy flow is:

- Unidirectional
- Follows 10% law

Matter cycles:

- Carbon cycle
 - Nitrogen cycle
 - Water cycle
-

Food Chain

Linear transfer of energy.

Example:

Grass → Rabbit → Fox

Food Web

Interconnected food chains.

More stable than single food chain.

Ecological Pyramids

Three types:

1. Pyramid of numbers
2. Pyramid of biomass
3. Pyramid of energy

Energy pyramid always upright.

Community Ecology

Study of interactions among populations.

Characteristics of Community

1. Species diversity
 2. Dominance
 3. Stratification
 4. Succession
-

Frequency

Frequency measures:
How often a species occurs in a given area.

Formula:
Frequency (%) =
 $(\text{Number of plots containing species} / \text{Total plots}) \times 100$

Life Forms (Raunkiaer Classification)

Based on position of perennating buds:

- Phanerophytes
- Chamaephytes
- Hemicryptophytes
- Cryptophytes
- Therophytes

Biological Spectrum

Distribution of life forms in a region.

Indicates:

- Climate type
 - Vegetation pattern
-

Integration of Unit 6

- ✓ Microorganisms are fundamental life forms.
 - ✓ Growth kinetics explains microbial multiplication.
 - ✓ Plants regulate water and mineral balance.
 - ✓ Ecosystems maintain energy flow and nutrient cycling.
 - ✓ Ecology connects organisms with environment.
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